ВОЕННО-ТЕХНИЧЕСКИЙ СБОРНИК БАСТИОН
ЖУРНАЛ ОБОРОННО-ПРОМЫШЛЕННОГО КОМПЛЕКСА

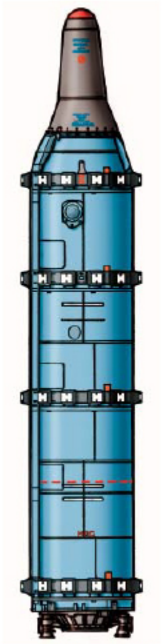
March 28, 2017

MISSILE COMPLEX D-5 WITH R-27 ROCKET
MISSILE COMPLEX D-5 MISSILE R-27

At the initial stages of work on creating a modification of the Project 705 nuclear submarine with ballistic missiles, the available data on domestic missiles of the complexes being developed at that time was used. However, in relation to the Project 705 nuclear submarine, due to the significant weight and size characteristics, these missiles led to significant architectural changes to the base ship. Therefore, on the initiative of SKB-143, A.P. Aleksandrov raised the question of the possibility of creating a small-sized, but quite effective Polaris-type ballistic missile to missile developers. Such missiles in the amount of eight units made it possible to assemble a compartment that fit into the ship. At the same time, a nuclear missile carrier would have a minimum displacement and high underwater speed. It would be inferior to the US missile carriers, which had 16 Polaris missiles, in terms of the number of missiles, but would have a 2-3 times smaller displacement. At the end of 1960, a letter was received from SKB-385, chief designer V.P. Makeev, to SKB-143 with the expected data on the rocket, the stages and timing of its creation.

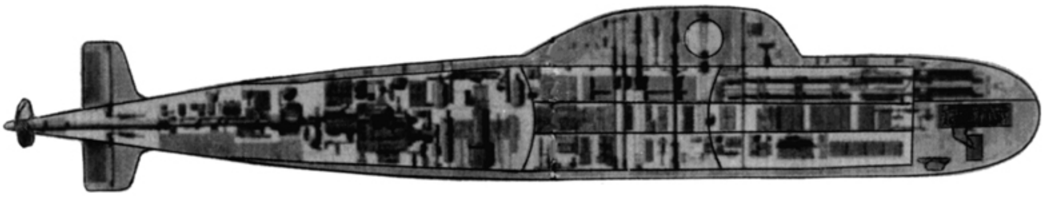
In accordance with the decision of the Commander-in-Chief of the Navy, SKB-143 began work on the preliminary design of the nuclear submarine pr.705B. A draft tactical and technical specification was developed and agreed upon with the Central Research Institute of VK.

Government Decree No. 485-201 of May 27, 1961, in development of the Government Decree of June 23, 1960, set the creation of an experimental submarine of Project 705 (Project 705B) in the version with 8 small-sized ballistic missiles in silos with a diameter of 1.6-1.7 and 9.5m long. Initially, work was carried out on an anti-ship ballistic missile with homing to destroy, primarily aircraft carriers. Initiative and in parallel with the RT-15M solid-fuel missile, work was carried out on a missile to destroy ground targets with the dimensions of the silo, like an anti-ship missile with homing4. The obtained design results gave rise to the chief designers (V.P. Makeev, A.M. Isaev, N.A. Semikhatov) to propose in December 1961 a two-stage development of the D-5 complex: with a ballistic missile to destroy ground-based strategic objects and with a ballistic missile for hitting mobile surface targets, primarily aircraft carriers. The last missile was supposed to compete with the missile launcher of the P-6 complex developed by V.N. Chelomey at OKB-52 GKAT.



Ракета Р-27 (4К10)

Work on the D-5 complex began in accordance with Resolution of the Central Committee of the CPSU and the Council of Ministers of the USSR No. 386-179 of April 24, 1962. The D-5 missile system was developed with the R-27 (4K10) missile to hit ground-based strategic targets at ranges of up to 2300 km (the missile was originally supposed to have a firing range of 1800 km) and with the R-27K (4K18) missile to hit large-displacement surface ships at a distance of up to 800 km. The decree specified the dimensions of the missile (length 8.7 m, caliber - 1.4 m) to ensure the possibility of installation in silos with a height of 9.5 m and a diameter of 1.7 m located on nuclear submarines pr 705B and 667A. Flight tests of missiles with a ballistic warhead were planned for the first half of the year, and with a homing warhead - at the end of 1964.
In accordance with the post Resolution of the Central Committee of the CPSU and the Council of Ministers of the USSR dated February 15, 1963 No. 202-73, the permissible length of the rocket increased by 200 mm, the diameter reached 1.5 m without changing the dimensions of the shaft . With the transition to new fuel, the maximum range increased to 2500 km for a missile with an unguided warhead and to 1100 km when using a homing warhead.
The main carrier of the D-5 missile system was to be the Project 705B nuclear submarine. SKB-143 specialists reviewed studies and proposals for the creation of missile weapons with an increased range on the basis of the D-5 complex and agreed on a protocol on the direction of further work on the Project 705B ship. G.Ya. Svetaev was appointed chief designer of the nuclear submarine pr.705B. In search of an optimal solution and determination of the main elements of the ship, options for placing missile weapons on a submarine were worked out.



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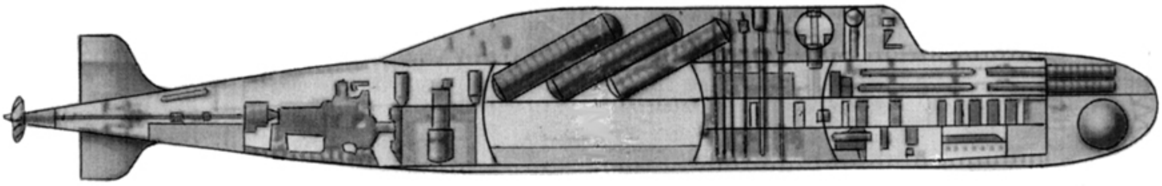
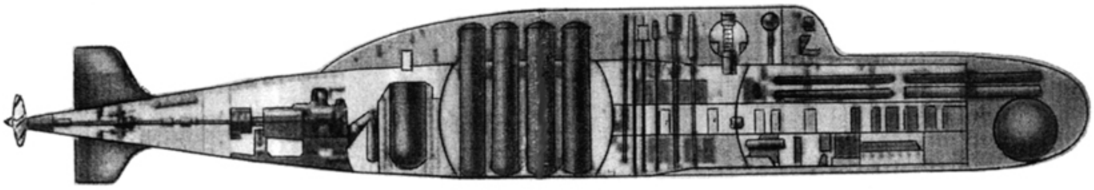
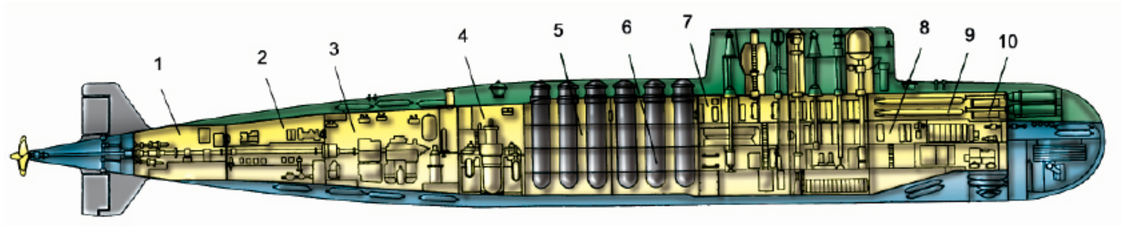




Based on the main technical solutions adopted in the preliminary design 705, SKB-143 developed pre-design designs: 705A - a submarine armed with Amethyst-type missiles and 705B - a submarine armed with small-sized ballistic missiles RK D-5. Pre-design projects 705A and 705B were carried out in SKB-143 with maximum unification both in the placement of the main equipment and in the design of the hull with the preliminary design 705. According to these projects, the hull of the Project 705 submarine provided for the insertion of one compartment with missile weapons with minimal changes in the design of adjacent compartments . On the Project 705A submarine it was planned to place 8 Amethyst-type missiles in inclined containers, and on the Project 705B submarine - 8 ballistic missiles of the D-5 complex in vertical missile silos. Pre-design designs 705A and 705B were completed in 1962.



Продольный разрез подводной лодки проекта 705Б:

1 - кормовой отсек; 2 — отсек вспомогательного оборудования; 3 — турбинный отсек; 4 — реакторный отсек; 5 - ракетный отсек; 6 — шахта баллистической ракеты; 7 — отсек центрального поста; 8 - торпедный отсек; 9 - запасная торпеда; 10 — торпедный аппарат

During the period of intensive activity on the preliminary design, work on it was unexpectedly closed for SKB-143. As it later became known, after persistent appeals from the chief engineer of TsKB-16 N.F. Shulzhenko to the chairman of the State Committee for Shipbuilding (report dated October 18, 1962), it was decided to transfer work on nuclear submarines pr. 705A and 705B to TsKB -16. In pursuance of the order of the State Committee for Shipbuilding dated December 11, 1962, work on this project at SKB-143 was stopped, and the relevant information was sent to all contractors and interested organizations. Further work on missile versions of the nuclear submarine Project 705 was carried out at TsKB-16 under the leadership of chief designer V.V. Borisov. This work was carried out in 1964-1965: projects 686 (formerly project 705A) and 687 (formerly 705B). The design of the Project 687 submarine was carried out by TsKB-16 using the main equipment developed for the Project 705 submarine.

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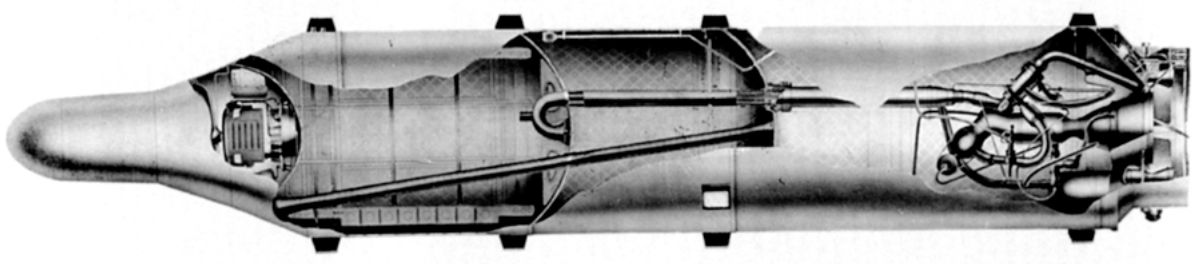
The preliminary design of the 687 (705B) nuclear submarine was completed at the end of 1964 by TsKB-16 in pursuance of Resolutions of the Council of Ministers of the USSR No. 485-210 of May 27, 1961, No. 670-27 of August 6, 1964 and No. 680-

280 of June 10, 1964 .
The project was developed in 4 options and 2 sub-options. The submarine was supposed to carry 12 missiles. The main difference between the options from each other was the type of polyurethane foam, technical equipment and other power equipment. In 1965, it was proposed to replace the missile system on the boat with a D-5M with improved characteristics. In August 1965, the preliminary design for 687 was approved. A version of the Project 687 submarine with 12 silos for D-5 missiles was developed. TsKB-16 carried out studies on the deployment of other missile systems on submarines, including D-9 with intercontinental missiles. Despite the completion of the preliminary design of Project 687 (705B), it did not receive further development, mainly due to problems that arose during the creation of the Project 705 (705K) nuclear submarine. Officially, work on the project was closed by order of the Main Directorate of the Navy of June 28, 1969. Subsequently, the main carrier of the D-5 missile system became the Project 667A nuclear submarine.



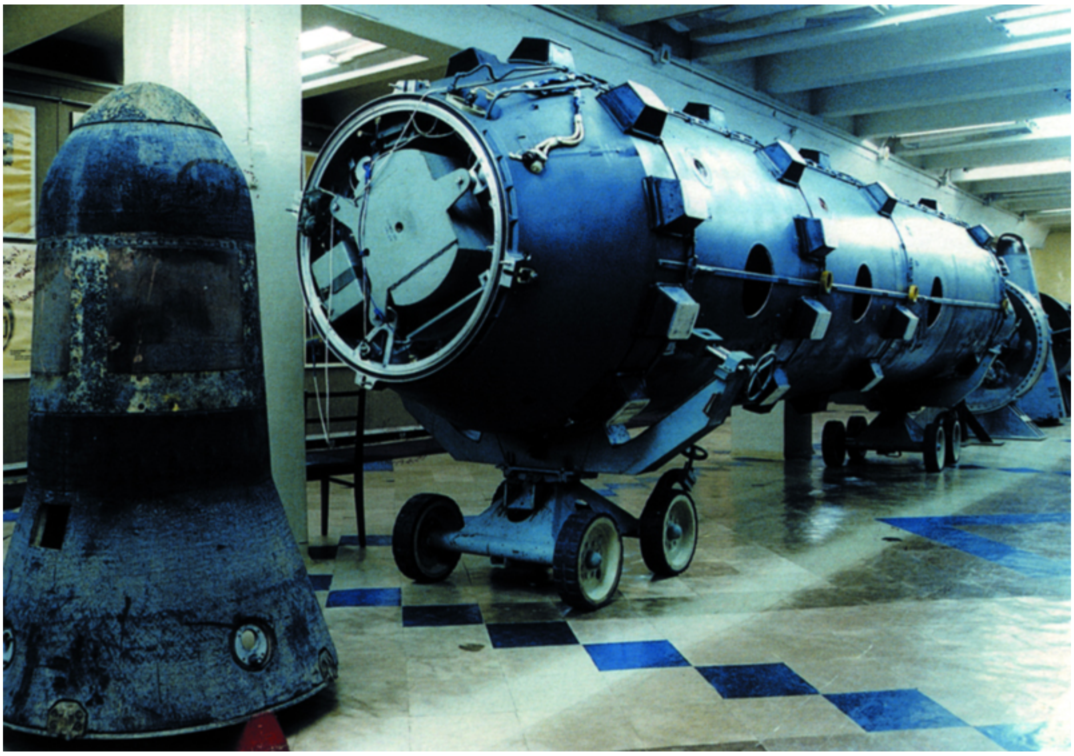
SLBM R-27 (4K-10) is a single-stage missile with a liquid fuel engine. She is the founder of modern marine liquid rocketry. On the R-27 missile, for the first time from the USSR SLBM, “wafer” structures of shells and bottoms were introduced, bimetallic connections of steel and aluminum parts, double-layer bottoms were created, and factory fueling and ampulization were used. The rocket body is all-welded from aluminum alloys (AMG-6). In the tail section of the rocket there were two yokes, along the length of the body there were several belts of rubber-metal shock absorbers, which, under acceptable launch conditions, ensured a stable exit of the rocket from the shaft at a speed of 30 m/s.
The control system for the R-27 missile was developed by NII-592 (NPO Automation), the command devices for it were developed by NII-49. For the first time, NII-592 specialists included a gyro-stabilized platform in the control system. To increase the accuracy of control of the flight range and trajectory, regulation of the parameters of the rocket's movement in three directions in space has been implemented. The control system equipment was arranged in a sealed volume formed by the hemispherical upper bottom of the oxidizer tank.

Компоновочная схема ракеты Р-27

For the first time, starting with the R-27 rocket, a gyro-stabilized platform is being introduced into the control system to implement an inertial coordinate system in flight.
The introduction of gyroplatforms and the consistent use of modern scientific achievements in constructing models of the Earth's gravitational potential made it possible to create algorithms for solving the navigation problem with high accuracy for launches from the World Ocean.

The rocket used for the first time the D-10 (4D-10) engine "recessed" in the fuel tank with a central combustion chamber with afterburning of oxidized gas and a steering unit consisting of two oscillating combustion chambers, developed at KBKhM under the leadership of A.M. Isaev.
The path to maximum use of volume for fuel placement was made when creating the D-10 engine for the R-27 single-stage rocket by placing it in the fuel tank. This arrangement of the engines of an ampulized rocket became possible after the creation of an all-welded engine.
Placing engines in fuel tanks required increased density of parts, density of welds, high-precision methods for monitoring tightness and posed a number of other tasks, in particular, the task of completely eliminating micro-leaks that may remain in the metal. As a result, it was possible to ensure the durability and reliability of the factory-filled and ampulized rocket. This arrangement of the engine made it possible to radically reduce volume losses due to the maximum completeness of filling the volume of the propulsion system with fuel.
Other engine features. The main unit is made according to a closed circuit with afterburning of oxidative turbogas. The steering block is an open circuit. Engine start is single-pulse. When the steering unit reaches 50% of the mode, the striker is triggered, igniting the powder block of the starter of the turbopump unit of the central block. Thus, the steering unit starts first, and then the central one.

Reliable starting of the steering unit in the presence of mine backpressure is ensured by the following design and circuit features of the engine: significantly lower pressure loss in the gas generator lines than in the lines of the steering chambers, and earlier entry into the gas generator mode in relation to the steering chambers; increased power of the turbopump unit created by a powder starter, which also operates until the steering unit reaches a high (at least 50%) mode; low moment of inertia of the rotor of the turbopump unit of the steering unit, relative to the power of the unit.
The steering and central units can be stopped either simultaneously or separately. The specified ratio of fuel components is maintained by a system that includes: two Venturi tubes (one on the fuel line, the other on the oxidizer line); two spools comparing the pressures of the fuel and oxidizer (one compares the pressure in front of the Venturi tubes, the other - in a narrow section of these tubes); two throttles installed on the fuel line and, together with the spools, maintaining the fuel pressure equal to the oxidizer pressure at the compared points. This maintains equal pressure drops across both tubes and therefore equal component flow ratios. Such a system, first used on the D-10 engine, ensured that the ratio of fuel components was maintained with an accuracy of ±2% with a minimum pressure loss across the Venturi tube of about 5 atmospheres.
On the first copies of the engine, the set gas pressure in front of the injectors was maintained by the draft regulator of the central unit. Low-frequency pressure fluctuations arose in the engine, penetrating the afterburner with an amplitude of about 15 atmospheres. The installation of a flow regulator designed by the chemical machine design bureau, made according to the design bureau of chemical automation, made it possible to get rid of pulsations. Hot pressurization of both rocket tanks was applied.
The total heating of the fuel in the tank due to the heat from the "recessed" engine and from the hot supercharging at the end of operation is about 10°C.
The layout of the D-10 engine in a fuel tank has become a classic design for naval missiles R-27K, R-27U and the first stages of missiles R-29, R-29R, R-29RM and their modernized variants. At the same time, the D-10 engine was used as the engine of the first stage of the R-27K missiles without changes.
On the R-27 rocket, cable laying was first used in steel pipelines and fluoroplastic sleeves in a metal braid on the propulsion system and in an elliptical aluminum pipe in the onboard cable under the fairing. The elliptical pipe made it possible to fit into a structure with limited dimensions, and the use of metal pipes and fluoroplastic sleeves resulted in a gain in weight and an increase in guaranteed shelf life compared to rubber casings. For the R-27 rocket, for the first time, a series of special multi-contact small-sized sealed electrical connectors was designed, which were developed into a series of tear-off, shoot-through, feed-through connectors, "blind" docking connectors, about 200 designs in total.

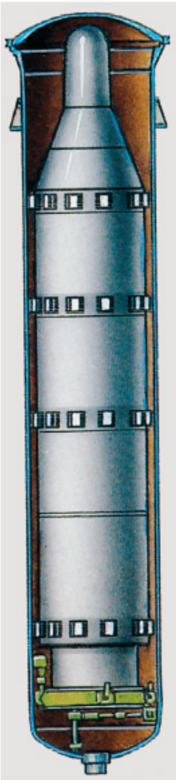


The nuclear ammunition of the R-27 missile was created by NII-1011, chief designer L.F. Klopov. The charge was developed by Design Bureau - 11, chief designer E.A. Negin. The main difficulty was the need to create a warhead that would be approximately two times lighter than the warhead of the R-21 missile.
The monoblock warhead of the R-27 missile made a significant contribution to ensuring the small size of the missile. Nuclear ammunition (chief designer L.F. Klopov) in comparison with the D-4 complex has almost half the weight, and its length is more than half a meter less in comparison with the ammunition of the R-21 missile.
The ammunition featured a radio-resistant non-contact detonation system, which was used in subsequent developments. And in the D-5 complex, when developing information support for the use of ammunition, the average statistical values of the thermodynamic parameters of the atmosphere and the deviation of ground pressure of the target’s geographic latitude for the month of launch were taken into account.

Моноблок ракеты Р-27

The selected two-stage charge had a power exceeding the half-megaton mark. The reduction in power compared to the R-21 warhead was compensated by an increase in the missile's firing accuracy. The charge was tested on Novaya Zemlya in 1966.
Small-sized automation was developed for the new warhead. The bottom of the head part also served as the housing of the low-voltage unit. The head body was made of aluminum-magnesium alloy and had the shape of a double cone with a rounded nose. The asbestos-textolite coating and the resulting detached aerodynamic shock protected the charge and automation from overheating in the final section of the warhead’s trajectory.
The rocket implements a set of circuit-layout and design-technological solutions that have become the basis for all subsequent types of liquid-propellant rockets: all-welded rocket body structures; introduction of a “recessed layout” of the propulsion system - the location of engines in oxidizer or fuel tanks; lack of traditional rocket compartments free of fuel (intertank, engine, instrument); the use of rubber-metal shock absorbers and the placement of elements of the launch system on the rocket; factory refueling of missiles with long-storable propellant components followed by ampulization of missiles; automated control of pre-launch preparation and salvo firing.
These solutions made it possible to radically reduce the dimensions of the missile, sharply increase its readiness for combat use (pre-launch preparation time was 10 minutes, the interval between missile launches was 8 seconds), simplify and reduce the cost of operating the complex in everyday activities.
After a comprehensive analysis of various types of devices, the developers of SKB-385 for breaking connections between the components of naval ballistic missiles took as a basis the use of the principle of explosive action using a detonating extended charge (EDC) of a cumulative type based on high explosives. The beginning was made with the creation of a system for the R-27 missile, in which the DUZ was used to separate the warhead from the carrier.

To create an air bell, a transition compartment was introduced into the small-sized R-27 missile, which is a two-hull all-welded structure of a complex configuration, covering the missile elements located behind the lower bottom and fitting into the contours of the launcher table. The transition compartment is hermetically joined to the bottom of the rocket body. The air bell is created by pressurizing the cavity of the transition compartment and displacing water from it through the lower section, which communicates with the surrounding space.
The transition compartment structurally tightly encloses the rocket elements, including the control chambers of the 1st stage engine. Therefore, in order to ensure the rotation of the control chambers in flight at specified pumping angles, as well as in order to reduce the flight weight of the rocket, the transition compartment does not participate in flight and remains on the launch table in the submarine shaft. To do this, it is attached to the rocket body with special explosive bolts.
The D-5 complex used a missile control panel (PURO), developed at NII-592. It was used to control pre-launch preparations, launches, and complex routine checks of missiles in an automated, centralized mode. The ship's control system made it possible to fire ballistic missiles in one salvo.



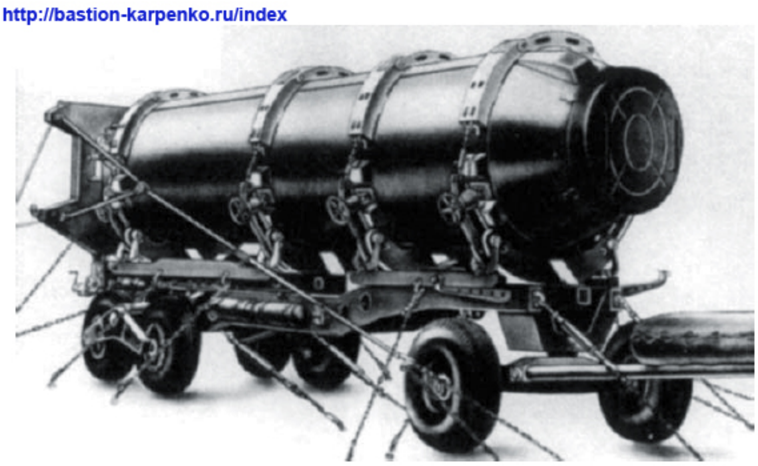
When designing the complex, various types of silo launchers were considered, including those with a “dry” start. Options for shock absorption of the rocket in the shaft were considered: rubber shock absorbers (shaft diameter 1.7-1.8 m) and spring shock absorbers (shaft diameter 1.8-2.1 m). The launcher had a significant impact on the formation of the missile system as a whole; first of all, it determined the number of silos and missiles on the submarine.
Initially, the development of launchers SM-88 for the D-5 complex and SM-86 for the test bench was supposed to be carried out at TsKB-34 under the leadership of chief designer E.G. Rudyak, which created the silo launcher for the R-13 and R-21 missiles. Since 1962, this design bureau has been developing the SM-139 launcher for the Project 667A nuclear submarine. TsKB-34 proposed creating a launcher with mechanical shock absorption, which would make it possible to place only 5-6 launchers with missiles on a submarine. SKB-385 was against this decision and proposed reducing the gap between the missile and the launcher through the use of rubber shock absorption, which made it possible to place up to 16 missiles on the same submarines. The hydraulic drive of the shaft cover ensured its opening (rotation at an angle of 120 degrees) in 1 minute.
With the help of scientific and technical studies of the 24th Institute of the Navy at the Agat Research Institute (chief designer R.R. Belsky), the first combat information-controlled system (CIUS) “Cloud” was created for the D-5 complex, which had no analogues in the world . It comprehensively solved a wide range of tasks for controlling the combat activities of the nuclear submarine pr. 667A, including the firing of torpedo weapons and ballistic missiles.
The creation of the second generation of naval strategic weapons (D-5 missile system) coincided with the intensive development of digital computer technology and their implementation in ship information and control systems. A fundamentally new achievement in this area was the development by the Marine Research Institute No. 1 (MNII-1), later the Central Research Institute "Agat", of the first domestic combat information and control system (CIUS) "Tucha" (chief designer R.R. Belsky) for Project 667A missile submarine.
The Tucha system was created as a single integrated multi-purpose system for a comprehensive solution to a wide range of tasks of controlling the combat activities of a submarine and the combat use of all types of its weapons. It had no analogues in the world and opened a new class of radio-electronic weapons for submarines, based on digital computing technology. “Cloud” consisted of four functionally complete circuits (or subsystems): information and control, navigation, torpedo, and missile.
The presence in the system of two parallel operating digital computers (DCMs) ensured control of the correctness of information input (comparison of checksums), reliability of calculations (comparison of calculation results), and increased reliability of operation in all modes of use.
In general, organizing a missile attack on coastal targets included solving the following tasks: preparation (according to the Navy) and storage of information about targets, retrieving information about targets assigned for attack (coordinates, aiming

points, etc.); selecting a starting point from which reach
of designated targets is ensured, moving to this point (if necessary); generation of data for firing and inputting them into the rocket during pre-launch preparation.

Firing could be carried out either as single missiles at one target, or as a two-part salvo of eight missiles at one or eight different targets. Target designation for calculating the flight mission of the missiles was entered from punched cards.

The successful development of the missile firing control circuit together with the ship's control system equipment and other systems of the missile complex became the basis for the implementation of automated pre-launch preparation, salvo firing and post-launch maintenance of the submarine and missile complex systems. Avoiding “manual” preparation for firing, ensuring the rate of fire and manifold increase in the ammunition load of missiles on a submarine became one of the main achievements of naval missile technology at this stage.

The first firing control system for strategic missiles from nuclear submarines, developed by the Agat Research Institute, was the R-27 missile firing system of the D-5 complex, which was part of the Tucha control system. To automate the pre-launch preparation processes, NPO Agat (chief designer I.F. Musatov) developed the first domestic digital computer for submarines, its productivity was more than 50,000 operations/s. The initial data for firing, including the warhead, was generated by the first combat information and control system “Tucha”. The adoption of the Tucha BIUS and its successful operation in the fleet became the impetus for the emergence of a large range of systems of a similar class for arming nuclear submarines of various projects: the Almaz type for II generation nuclear submarines and the Omnibus type for III generation nuclear submarines both multi-purpose and strategic.



Ракета Р-27 на транспортной тележке

The complex of ground equipment for the D-5 missile system was developed at the GSKB (KBTM). It was supposed to ensure ground operation of the R-27 and R-27K missiles during passage from the manufacturing plants to the submarine. The units were developed unified for two types of missiles and ensured the storage of ampulized missiles in a mobile technical position, and also maintained the required temperature conditions during storage and transportation.

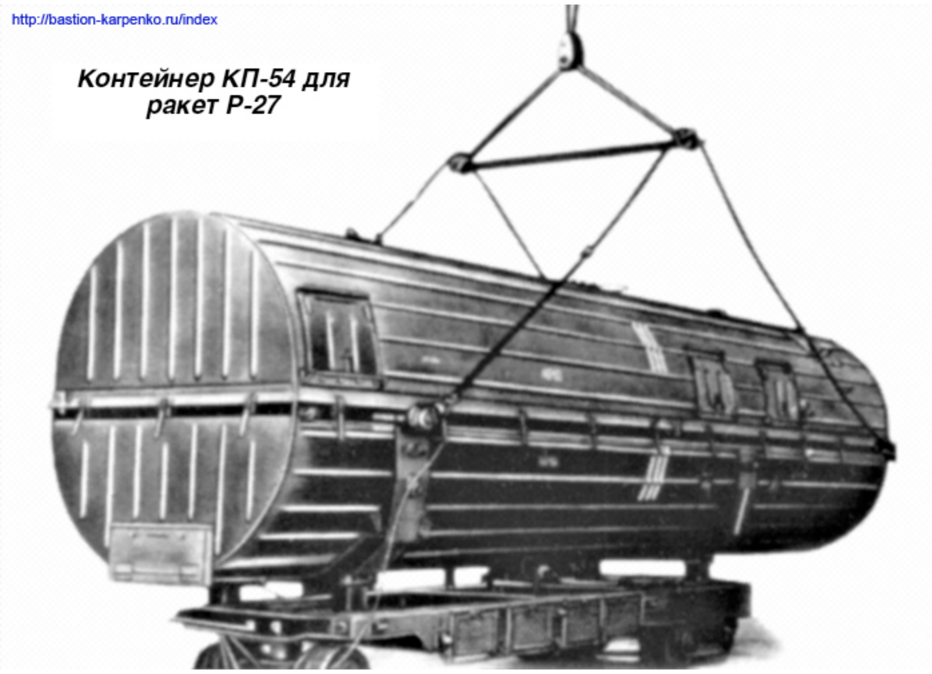
In 1962, GSKB-KBTM began creating ground-based equipment for missiles ampulized after factory refueling: the strategic R-27 and the anti-ship R-27K of the D-5 complex. Ground equipment units for these missiles were largely unified. There was no longer a need to have rocket refuelers with oxidizer and fuel, but it was necessary to use mobile containers for draining fuel components from rockets (tankers for oxidizer and fuel), and equipment for neutralizing the components.

For the first time, the ground equipment included isothermal railway cars, which provided temperature control of the missiles during their transportation, gas control of the cargo compartment and had a fire extinguishing system and means for localizing fuel leaks from the missile tanks.

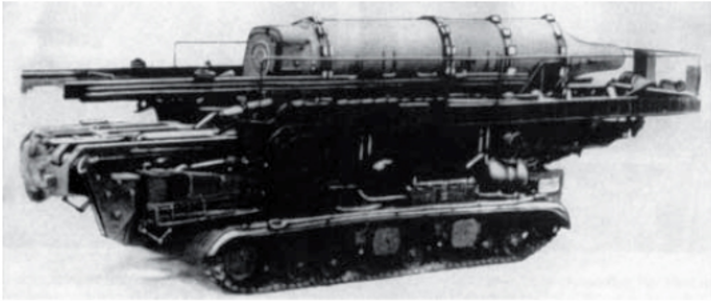
To store missiles in mobile technical positions, isothermal containers with a temperature control system have been created. To deliver missiles to a technical position, a motor transport unit has been developed that transports the missile both in an insulated container and without it. The unit has increased maneuverability and allows, in conditions of mobile technical positions, to carry out work together with other ground-based equipment to prepare the missile for loading onto a submarine.

For the storage and intra-base transportation of missiles in a container or without it, a hangar storage trolley was created, and for its towing in the missile base facilities, an explosion-proof electric tractor was created. To ensure air transportation of the missile, a special aircraft trolley was included in the equipment.

To reload the submarine with missiles (in combat conditions), spare unequipped berths were provided, from which loading should be carried out with special units delivering the missile from mobile technical positions. Loading must be ensured in difficult hydrometeorological conditions with sea waves up to three points and wind speeds up to 20 m/s.



Real mutual movements of the submarine and the missile in such conditions were inevitable, but the initial data on them were overestimated several times, which sharply complicated the design of the created lifting and docking units. At the same time, further work on putting such units into operation was considered inappropriate for a number of reasons:
– the duration of loading missile ammunition onto the boat;
– the need for highly qualified service personnel and a long training period, which practically excluded the possibility of using enlisted men and senior officers of conscript service to work on such a unit;
– the complexity of maintenance and repair of the unit, especially its high-precision hydraulic equipment, which requires factory conditions and appropriate equipment, which the Navy bases did not have.
In addition, such lifting and docking units could not become universal means of loading, because each of them was tied to a specific type of missile and submarine. For the following offshore complexes, the requirement for reloading from unequipped berths was not made, since views on the need to reload boats in the containment strategy were revised.
As a result of the tests carried out for the D-5 complex, the loading of R-27 missiles was adopted using a Project 1505 ("North") missile carrier equipped with a jib crane as the main lifting means - a floating loader - and a boom pneumatic wheel as an auxiliary lifting device. crane, created according to the technical specifications of GSKB-KBTM, for tilting missiles using a two-crane scheme. In addition, a corresponding set of lifting equipment was developed.



Опытный установщик ракет Р-27 на шасси танка Т-10

Транспортер ПР-55

Машина для слива компонентов топлива ЗАК-53Ц

In total, the 4N10 ground equipment included 46 units, of which 31 were newly created and 15 were mass-produced, of which 21 units were developed by the Transport Engineering Design Bureau. The complex did not include refueling means; the rocket was refueled at the manufacturer, but for emergency drainage of fuel components, mobile tanks ZAK-52Ts and ZAK-53Ts were created, and the standard 8T311M product was used to neutralize the tanks. Two schemes were developed for loading missiles onto a submarine: using jib cranes in "still water" conditions and winds of up to 10 m/s; with a special lifting and docking unit PS-7 under wind and wave conditions. The PS-7 unit could ensure that the submarine was loaded with missiles in two rows without re-mooring it on the other side. When using the PG-7 loading device, developed at the GSKB GKOT, the loading time for a missile on a submarine was up to 80 minutes, and for an ammunition load of 12 missiles - 16 hours.
Flight tests, testing and operation of missiles using the 4N10 complex were carried out: during throw tests from a floating test bench and an experimental submarine at the Southern Sea Test Site; during fitting tests of ground equipment with a volume-weight mock-up of a rocket at an industrial test site in Zagorsk (now Peresvet); when providing launches from a ground stand at the test site in Kapustin Yar; during joint tests from a submarine at the Northern Sea Range.
This scheme for testing a rocket and its ground-based equipment has become traditional for all subsequent sea-based missiles with the creation of special ground-based launch complexes (stands) at the Northern Sea Test Site in Severodvinsk.
The 4N10 ground equipment for the R-27 missile successfully passed all stages of testing and was accepted into service and into regular operation as part of the D-5 missile system. The Transport Engineering Design Bureau was awarded the Order of the Red Banner of Labor.
During the work, the developers encountered operational problems at Navy bases. It was necessary to develop and issue initial data and technical requirements for basic engineering structures and transport communications in order to retrofit them. Since then, industry has become constantly involved in the preparation and acceptance of Navy bases for operation with the next missile in accordance with the tactical and technical requirements issued by the fleet and the initial data for the missile system and ground equipment.
The development of small-sized second-generation rockets posed new challenges that required the use of measuring instruments produced by specialized enterprises. Modernized on-board telemeasurement systems and new transponders of the external trajectory measurement system were used.

Cadmium-nickel batteries began to be used as power sources for on-board equipment, instead of bulky ampoule silver-zinc batteries. Since the dimensions of second-generation missiles did not allow, in some cases, the use of serial measuring instruments, the development and modification of measuring instruments was carried out. The Mechanical Engineering Design Bureau created heat-resistant antennas for small-sized units with increased speed in the atmosphere.

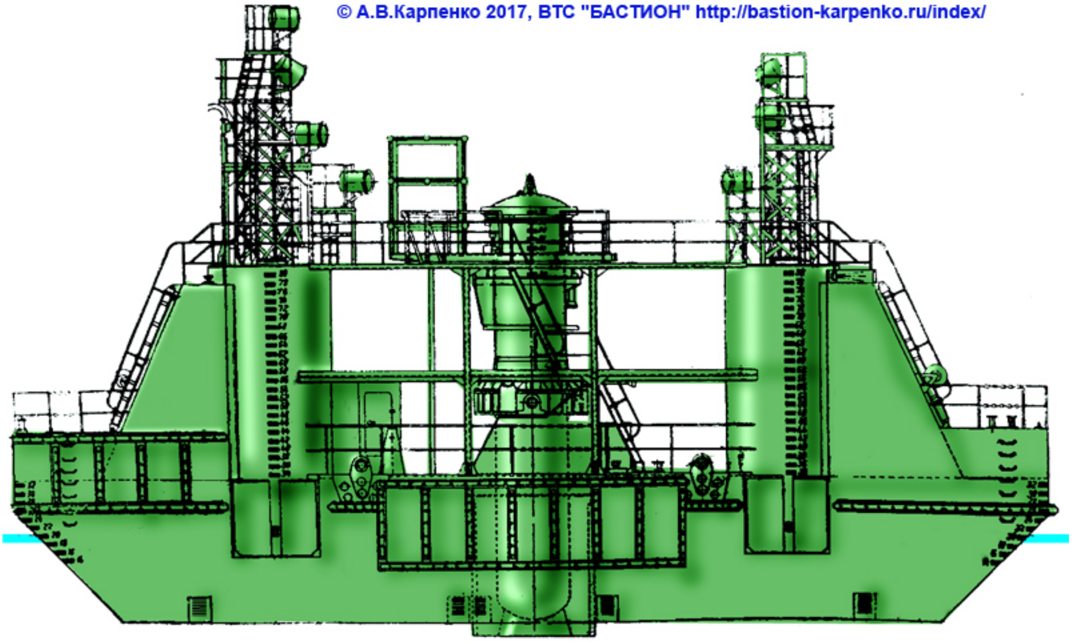
For the R-27 rocket, telemeterers had to solve what seemed to be an unusual task: to develop a system for rescuing the warhead after passing through dense layers of the atmosphere for its subsequent defect detection. The parachute was developed by the Research Institute of Landing Equipment, and the automatic parachute deployment was developed by the head telemetry department of the State Research Center. Since then, the development of automatic rocket payload recovery has been carried out by telemetrists, including during commercial launches of sea rockets.

Starting from the stage of mass production of R-27 missiles, telemeasurement tools, called “small telemetry”, were created to monitor parameters during batch shooting and training firing. Radio telemetry systems, external trajectory measurement systems and matching devices were placed in special capsules (containers) at the warhead sites. A small number of sensors, high-frequency connectors and cables, mounting locations for antennas were installed on the rocket during manufacture and were part of it throughout its operation. Installation of small telemetry on a missile instead of standard warheads could be done both at a technical position and on a missile loaded into a submarine's silo. In addition to missiles with low telemetry, for shooting from the batch it was planned to equip each batch with control telemetry with a volume of telemetry measurements close to the volume of measurements during flight tests.

During the development of the D-5 complex, two experimental R-27 missiles were tested. The accidents were initiated by the destruction of the high-pressure oxidizer pipeline located in the fuel tank. Tests confirmed the absence of explosive processes (a consequence of the use of self-igniting fuel). The front part of the rocket was ejected from the silo without a significant increase in pressure in the silo.

Due to the fact that the designs of the R-27 missiles, submarine silos and launch devices were fundamentally different from similar components of previously developed missile systems, when creating the D-5 complex there was a need to test an underwater launch from a floodable stationary floating stand and from an experimental submarine.

The development of a technical working project for the conversion of the Project AB611 submarine into an experimental submarine of Project AB611D5 for development and testing of the D-5 missile system, including flight design and joint tests, began at TsKB-16 in 1962. But soon the design was stopped due to the lack of a ship-based missile control system and was not resumed in the future.



In the second half of 1962, TsKB-16 (chief designer Ya.E. Evgrafov) developed a project to re-equip the PSD-7 stand for testing the underwater launch of R-27 missiles of the D-5 complex, the stand was designated PSD-5. In August 1963, working drawings for the stand were transferred to plant No. 444, its production was completed in 1965. The installation of the launch equipment on the stand was carried out by the Bolshevik plant, and the Sevastopol Ship Repair Plant simultaneously installed the equipment for the control station of the PSD-5 stand on the cable ship KS-4.

Основные характеристики стенда ПСД-5

Характеристики	Стенд ПСД-5
Разработчик	ЦКБ-16
Гл. Конструктор	Я. Е. Евграфов
Завод-строитель	№ 44
Состояние	Изготовлен в 1963 г.
Водоизмещение надводное, $м^3$	241
Длина, м	24, 0
Ширина, м	8, 6
Высота борта, м	3, 3
Осадка (с макетом ракеты), м	1, 95
Глубина погружения, м	до 50
Скорость буксировки, узлы	4, 0
Число пусковых шахт	1
Длина шахты с ПУ, м	9, 75
Внутрениий диаметр шахты, м	1, 70
Допустимое волнение, баллов	до 3, 0
Допустимая скорость ветра, м/с	до 10, 0

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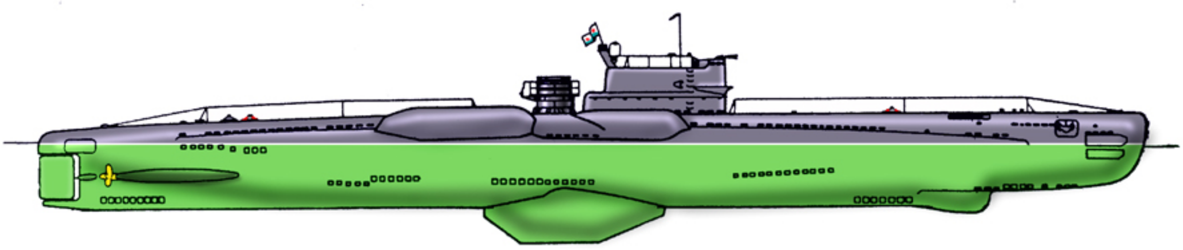
By decision of the Military-Industrial Complex of the Supreme Council of National Economy of August 7, 1963, TsKB-16 began designing a Project 613D5 submarine stand (chief designer Ya.E. Evgrafov), it was converted from a Project 613D7 submarine. The submarine was equipped with one shaft with a length of 9.75 m and an internal diameter of 1.7 m. Already in November 1963, the working documentation for the ship was transferred to plant No. 444. When launching missiles, the Project 613D5 submarine could have an underwater speed of 3.0 - 5.0 knots, the accuracy of holding the boat when firing was: in depth +1 m, in roll and trim +3 degrees. and at the rate +1 degree. Due to the fact that the development of the R-27K missile for firing at sea targets was late, development of the D-5 complex was limited to testing the R-27 missile.



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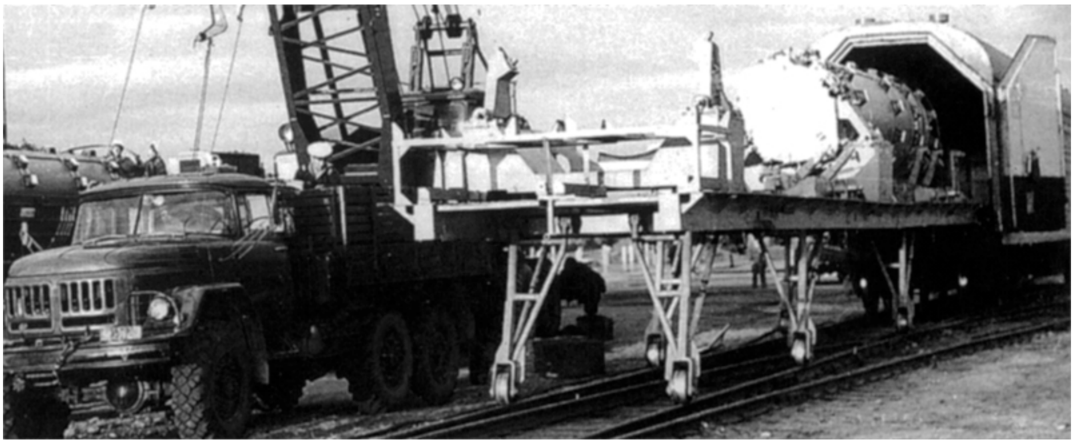
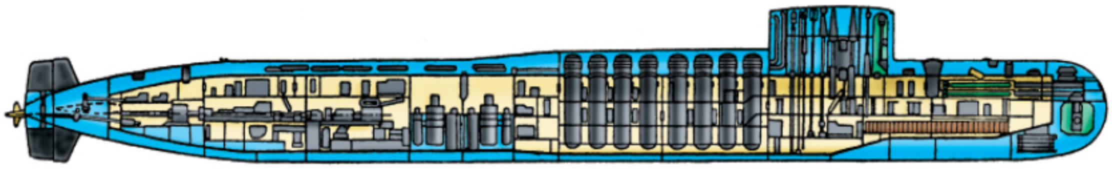
To study the conditions for the underwater launch of R-27 (4K10) missiles from a flooded silo, in September 1965 two launches of mock-ups of the R-27B missiles were carried out from a stationary stand PSD-5 from a depth of 40-50 m. After this, it was decided to lengthen the silo by 380 mm, the work was performed by specialists from plant No. 444. Four more launches were carried out in March - April 1966. Subsequently, the stand was converted to test R-27 missiles for fire and explosion safety, which was carried out in June - August 1966. After this, the systems on the Project 613D5 submarine were modified.

In January 1967, tests of full-scale mock-ups of R-27 missiles began from a submarine - stand pr.613D5; a total of six launches were carried out from a depth of 45-50 m at a boat speed of up to 4 knots.
At the first launches of the R-27B missiles, a significant excess of the calculated pressure values in the silo was revealed when the engine was started. Based on the results of these launches, computational studies and model tests, the problem was solved in the simplest way - by increasing the sub-missile volume by lengthening the shaft to 10.1 m. The latter became possible since by this time the placement of R-27 missiles only on Project 667A submarines had been determined. Based on the results of these tests, it was decided to move on to launching R-27 missiles from a ground stand.
Ground throwing tests of the rocket and fitting tests of ground equipment were carried out at NIIHSM (Zagorsk).



Flight tests of the first second-generation missiles R-27 and R-27K of the D-5 complex were carried out at the Kapustin Yar test site. Flight design tests of the R-27 missiles took place from a rocking stand at the Kapustin Yar test site. These missiles were delivered to the test site from the manufacturer in filled and ampulized form. Therefore, from the cycle of preparation for loading into the ground stand, which simulated a submarine shaft connected by cable channels to the command bunker, the operation of refueling the rocket with fuel components was excluded. But in case of need to drain the fuel, the test site had special mobile units for draining the fuel and oxidizer.
During tests from June 1966 to April 1967, 17 missile launches were carried out, of which five were emergency and one was unsuccessful. The start was unsuccessful. The first launches turned out to be emergency - the missiles fell on the territory of the test site, and the telemetry records of the Tral stations did not give an answer.
During the first launch, due to an error in the electrical circuit of the pre-launch service, the fuel tank in the stand shaft was overcharged and destroyed. During the second start-up, due to insufficient rigidity of the gimbal suspension of the gyro-stabilized platform, the control system was de-energized when the engine was started. During the third launch, until the 64th second of flight, due to a malfunction of the DOS-140G sensor, the command to throttle the engine was not received. The malfunction corrected itself, and at 83.4 seconds, as a result of insufficient thermal protection of the control system cables laid in the area of the engine nozzle, the emergency missile detonation system was activated. During the fourth start-up, due to the lack of thermal insulation, thermal damage occurred to the cable supplying the steering gears. As a result of processing telemetry data, insufficient rigidity of the gimbal wheel of the gyro-stabilized platform was revealed under longitudinal overloads occurring in flight. For this reason, a large lateral deviation of the head part occurred. During the tenth start-up, due to a manufacturing defect in the manufacture of the oxidizer shut-off valve of the engine steering block, spontaneous cut-off of the oxidizer occurred.
In addition to the indicated defects, the following significant comments were noted during the launch process. During the fifth and sixth launches, due to the increased aftereffect impulse of the main engine chamber, the rocket bodies collided with the warheads after their separation. To prevent similar phenomena, powder engines were introduced to deflect the rocket body.
During the seventh launch, due to the failure of the DOS-140G sensor as a result of clogging of the chamber cavity, the command to throttle the engine was not passed throughout the active phase of the rocket's flight until the preliminary shutdown command. During the ninth launch, the DOS-140G sensor did not work until the 87th second, then it worked for only 2.4 seconds. During launch, the point of impact of the warhead was deviated in direction. The most likely cause of this was a manufacturing defect in the lateral stabilization channel. During the fourteenth launch, thermal damage occurred to the cable to the steering gears due to the lack of thermal insulation.
The State Test Commission considered that the results of launches from a ground stand confirmed the safety of the launch and made it possible to make a decision to proceed to testing from a Project 667A submarine.
Flight tests of the R-27 missile from a submarine were carried out in Severodvinsk. The technical position was deployed in the installation and testing building of the test site. The Project 667A submarine was based at the manufacturing plant in Severodvinsk, from the pier of which missiles were loaded, then general tests and departure to the launch position in the White

Sea.
Tests of the D-5 complex were carried out on the submarine pr.667A (K-137), the first firing was carried out on August 28, 1967, the second - on September 27, 1967. Testing ended in October 1967, with six launches, including two-missile and three-missile salvoes.
The D-5 complex was adopted for service by Resolution CM No. 162-164, signed in March 1968, only with the R-27 (4K10) missile; the carrier ship of the complex was only the submarine pr.667A, equipped with 16 missile silos. The D-5 complex is designed to destroy strategic targets at medium ranges.
To manufacture R-27 missiles at the Krasnoyarsk Machine-Building Plant (Krasmashzavod), new technologies already mastered at the Zlatoust Machine-Building Plant were used: the production of aluminum cases and wafer structures of shells and bottoms; bimetallic connections of steel and aluminum parts; double-layer bottoms; implementation of blind joining of pneumatic and electrical connectors; factory refueling and ampulization of rockets. The R-27 missile ampulization complex was created at the Krasmash test base - Khimzavod in 1969. The first rocket was fueled, ampulized and delivered to the customer in September 1969. The rocket was manufactured until 1974.
With the creation of a new quality second generation of nuclear missile carriers, Project 667A, from the mid-1960s. the formation of a domestic strategic nuclear missile underwater system began. The first in this area were the commanders of submarines of Project 667A: V.L. Berezovsky, L.K. Zadorin, G.G. Loikkanen, A.I. Pavlov, V.V. Lobodenko, G.A. Shabalin, Yu.A. Voronov, A.I. Katyshev, G.F. Avdokhin and many others of this world's largest series of submarine missile carriers.



Подводная лодка проекта 667А

Work on the nuclear submarine Project 667A was specified by Resolutions of the Council of Ministers No. 316-137 of April 14, 1961 and N565-234 of June 21, 1961. In the technical project 667A, completed in 1961, options for a ship with 14 and 16 missiles of the D-5 complex were considered with a displacement of 7500 and 7250 m3, respectively. Initially, it was planned to place the ballistic missile system of the D-7 complex on the submarine (technical design of the submarine in 1962), but the revised technical design of the submarine pr.667A provided for the placement of the D-5 complex. The technical project was completed in 1963. The development of Project 667A was preceded by Project 667 of a nuclear submarine with 8 R-21 missiles of the D-4 complex. In 1961, it was decided to begin development of a new technical project 667A with 16 solid-fuel missiles of the D-7 complex, placed in stationary vertical silos. Later, when considering the technical project 667A, it was proposed to provide for the possibility of placing on the submarine, along with solid-fuel missiles of the D-7 complex, liquid-fuel missiles of the D-5 complex.
During the adjustment of the technical design, the incompatibility of the placement of these complexes was revealed, in addition, the development of the D-7 missile system was delayed, and in terms of its performance characteristics it was inferior to the D-5 complex. Taking into account these circumstances, the adjusted technical project 667A was approved in 1964 with 16 missiles of the D-5 complex. Missile launchers were placed in vertical stationary silos of equal strength. The shafts were located symmetrically to the blast furnace in two rows of 8 shafts in sections IV and V. The dimensions of the missile and the compact design of the launcher made it possible to place the missiles in silos with a diameter of 1.7 m and a length of 10.1 m.
The D-5 missile system was significantly superior to the missile systems of first-generation submarines in terms of basic performance characteristics. For example, compared to the D-4 complex, the firing range increased by 1.8 times, while the mass of the missile decreased by more than half.
The lead submarine, Project 667A, was laid down at Sevmashpredpriyatie on November 4, 1964, it received the tactical number "K-137" (commander V.L. Berezovsky, commander of the warhead-2 A.S. Ilyin), on August 25, 1966 it was launched and presented for State tests in the fall of 1967 (chairman of the government commission, Vice Admiral A.I. Petelin). On May 30, 1967, the missile carrier was demonstrated to the country's top leadership, headed by L.I. Brezhnev. The submarine "K-137" was later given the name "Leninets".
Submarines of Project 667A were the first multi-missile domestic missile carriers, on the basis of which the family of missile carriers of Projects 667B, 667BD, 667BDR, 667BDRM was subsequently created.

Основные характеристики ПЛ с ракетами Р-27 комплекса Д-5

Характеристики	ПЛ-стенд 613Д5	ПЛ пр. 667А	ПЛ пр. 705Б	ПЛ пр. 687
Разработчик	ЦКБ-16	ЦКБ-18	СКБ-143	ЦКБ-16
Состояние	передан на полигон в 1963 г.	переданы ВМФ в 1967-1974 гг.	проект 1962 г.	проект 1966 г. (проект 1964 г.)
Главный конструктор	Я. Е. Евграфов	С. Н. Ковалев	Г. Я. Светаев	В. В. Борисов
Водоизмещение, т: -надводное -подводное	1119 -	7640 11500	2365 3564	4792(4300)
Размеры, м: - длина - ширина - осадка	76,0 6,3 4,6	127,9 11,7 7,8	81,7 8,0 6,6	105 (99,0) 10,8 (10,8) 7,6
ГЭУ - мощность, л. с.	дизель-электрическая 4000	атомная ВМ-4-2 (ОК-700) 2х20000	атомная 40000	атомная БМ-40А 40000
Предельная глубина погружения, м	40-50 при пуске ракет	400	400	400(400)
Скорость полного хода, уз подводная/надводная	5,5/13,0	25-27/15-16	38/10	30/.(30-31/.)
Дальность плавания, миль (скорость, уз.)	8580	неограниченная	неограниченная	40000(40000)
Автономность, сут.	30	60	50-60	60 (60)
Экипаж, чел.	-	91	24	(24)
Ракетное вооружение: - Тип комплекса - число ПУ - число ракет	Д-5 1 1 (макет)	Д-5 16 16	Д-5 8 8	Д-5 (Д5-М) 8 (12) 8 (12)
Торпедное вооружение: - число 533-мм ТА - число 400-мм ТА	6 -	4 2	6 -	6 (6) -

During construction and operation, a number of Project 667A submarines were converted according to Projects 667AU, 667AT, 667AK and 667M. In the 70s, one Project 667A submarine was re-equipped along Project 667AM for the D-11 complex with the R-31 solid-fuel SLBM with an ammunition load of 12 missiles.

A large amount of work on maneuvering and controllability of the new submarine was carried out at the Central Research Institute named after. acad. A.N. Krylova. During the development of the missile carrier Project 667A, the intersectoral integrated system of target planning and control “Blue Bay” was introduced into production, and the “Zarya” system was introduced for the missile complex. In total, 34 Project 667A submarines (AU) were built at the shipyards of the Northern Engineering Enterprise in Severodvinsk and the Amur Shipyard in Komsomolsk-on-Amur from 1967 to 1974. These missile carriers were part of the 19th, 31st and 85th divisions in the Northern Fleet and the 8th division in the Pacific Fleet. During operation, the missile carriers made 590 trips with a total length of 41,300 days.

The operating voltage coefficient for the submarine pr.667A (AU) was 0.29. The creation of the entire Project 667A submarine system was estimated to cost about 20 billion rubles.

In October 1965, SKB-143 developed a technical project for the conversion of the nuclear submarine pr.671 to the D-5 ballistic missile complex (nuclear submarine pr.679). Chief designer G.N. Chernyshev, deputy chief designer A.V. Kuteynikov. Further work on Project 679 was stopped according to a telegram from the Main Directorate of the Navy dated October 23, 1965.

The D-5 complex provided simultaneous shelling of 2-4 targets located in the course sector +/-5 degrees (according to the design for the submarine pr.687 - +/-15 degrees, in reality for the submarine pr.667A - +5/-15 degrees). 8 missiles were prepared for launch (pre-launch preparation time 10 minutes). Firing was carried out in salvoes of 2-4 missiles with an interval between missile launches in a salvo of 5-8 seconds, between salvos - 3 minutes.

Accidents on submarines with missiles of the D-5 complex occurred: on the submarine K-219 in 1973, on the submarine K-4 during the Ocean-76 exercises in 1976, on the submarine K-219 in October 1986 in the Central Atlantic (boat sank).

During ground maintenance of missiles, over all the years of operation, only one case was an emergency - in 1971, in the Northern Fleet, a missile fell from a height of 7-10 meters.

Over the entire period of operation of the D-5 (D-5U) complex, about 600 missile launches were carried out, more than 10 thousand missile loading and unloading were carried out, and 590 combat patrols were carried out in various areas of the World Ocean.

The last R-27U missile was unloaded from the Project 667AU (K-430) SSBN of the Pacific Fleet on July 1, 1994.

CHARACTERISTICS

Developer SKB-385 GKOT (KBM)
Ch. designer V.P.Makeev
Leading designer Yu.M.Ivanov
Manufacturer Zlatoust MZ and Krasnoyarsk MZ
Name according to START RSM-25
NATO code SS-N-6 mod 1
Type of complex missile system with a ballistic missile with underwater launch for firing at stationary coastal targets and large surface ships, second generation
Submarine carrier ships Project 613D5, Project 605, Project 667A, 687
In service since 1968
R-27 missile (4K10)
Firing range, km 2400-2500
Firing accuracy (CA), m 2700-3000
Trajectory height, km 620
Warhead:
- monoblock detachable type with thermonuclear charge
- length, mm 1710
- weight, kg 650-900
- ammunition developer VNIITF2
- chief designer: L.F. Klopov
- charge power, Mt: 1.0 (0.6-1.2)
Control system: inertial
- developer: Research Institute of Automation
- Ch. designer: N.A. Semikhatov
Controls and stabilization: two steering combustion chambers in gimbal suspensions
Aiming devices:
-developed by Central Design Bureau "Arsenal"

-ch. designer S.P. Parnyakov
- work supervisor O.S. Vlasenko
- PP-110 optical-mechanical device for monitoring the position of NK devices on a submarine
- PP-110T optical-mechanical device for monitoring the position of the GPS on the rocket
- PP-105M optical-electronic angle measuring system for measuring the angle of rotation of a rocket in a silo
Launch type: underwater
using its own engine from a flooded shaft (“wet”)
Launch depth, m: 40-50
Number of stages: 1
Dimensions, mm:
- full length 8890-9060
- length without head part 7.1
-max. body diameter 1.5
- yoke diameter 1720
Starting weight, kg: 13940-14200 (14300)
Filled rocket weight, kg:
- without warhead 13844
- with warhead 14536
Fuel: UDMH (heptyl)
Oxidizer:
nitrogen tetroxide AT (amyl)
Rocket body: welded from aluminum alloy with wafer structure6
Propulsion system:
- type three-chamber liquid-propellant rocket engine with one propulsion chamber and two steering engines
- developer of KB KhM (OKB-2)
- Ch. designer A.M. Isaev
- leading designer A.A. Bakhmutov
- engine thrust in vacuum, t 26
- operating time, sec 128.5
- hull material steel
Total
service life, years 13
Type of pre-launch preparation: automated1

LAUNCHER:
-Shaft type 4S10 with a rubber-metal shock absorption system located on the rocket6
DeveloperSKB-385 GKOT (KBM)
Work manager Yu.P.Grigoriev
Manufacturer plant "Bolshevik"
Condition series from 1964 to 1970
Launcher dimensions, m:
- length 9.75 (10.1)
- diameter 1.7 (1.9)
Shaft volume, cubic meters: 28.49
Number of rockets 1
Type of rocket shock absorption: rubber-metal
- manufacturer "Red Triangle" plant
Temperature, hail C 0-30
Relative humidity, % 98

SHIP CONTROL SYSTEM:
Developed by the Automation Research Institute
Chief Designer N.A. Semikhatov
Number of missiles in a salvo 4 and 8
Launch conditions:
- submarine speed, knots up to 4-5
- wind speed, m/s up to 20
- sea waves, ball. up to 5
- latitude of the starting point, degrees. north latitude up to 85
- water temperature, degrees -2 / +30 -
air temperature, degrees -30 / +50
Computer system:
- Record type
- developer NII-49 (TsNIIPA)
- Ch. designer O.V. Nosikov

GROUND EQUIPMENT:
Developer KBTM
Transport unit PR-55
Electric tractor: highly maneuverable ETV-50

- purpose: for work in the preparation shop and storage

Field storage unit KP-5 (KP-5M)
Thermostatic unit UTS-70S
- automatic operating mode
- number of serviced containers with missiles 18

Isometric container KP-54
Isometric railway cars 43-10 and 5Yu96F
Lifting and docking unit PS-7
Mobile tanks ZAK-52Ts and ZAK-53Ts
Means for neutralizing fuel tanks 8T311M
Hangar trolley PR-75

A.V. Karpenko, BTS “BASTION”, 03/22/2017

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RESEARCH ON MODERNIZATION OF THE D-5 MISSILE COMPLEX
D-5U MISSILE COMPLEX WITH R-27U ROCKET
PROPOSAL FOR THE USE OF R-27 ROCKET FOR GROUND silos
D-5 MISSILE COMPLEX WITH R-27K (4K18)
MISSILE COMPLEX PROJECT OF D-5ZH AT MISSILE COMPLEX
HIGH SUBMARINE MISSILE CARRIERS STRATEGIC PURPOSE PROJECT 667A (667AU)
PROJECT 687 (705B) NUCLEAR SUBMARINE WITH BALLISTIC MISSILES
MARINE COMPLEXES WITH BALLISTIC MISSILES
STATE ROCKET CENTER NAMED AFTER ACADEMICIAN V.P. MAKEEVA (GRC MAKEEVA)

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